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SPECIFICATION

TITLE

Method For Calibrating an Engraving Amplifier

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BACKGROUND OF THE INVENTION

The invention relates to the field of electronic reproduction technology and relates to a method for calibrating an engraving amplifier in an electronic engraving machine for engraving printing cylinders for gravure printing.

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In an electronic engraving machine, an engraving member with an engraving stylus as a cutting tool moves at a rotating printing cylinder in the axial direction. The engraving stylus, which is controlled by an engraving signal, cuts a series of cells into the surface of the printing cylinder. The engraving signal is formed in an engraving amplifier by superimposing image signal values with a periodic vibration signal. While the vibration signal effects an oscillating lifting motion of the engraving stylus for the purpose of generating the engraving raster, the image values which represent the tone values between "light" and "dark" which are to be reproduced determine the geometric dimensions of the engraved cells.

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So that the cells that are engraved on the printing cylinder have the desired tone values as prescribed by the image signal values, a calibration of the engraving amplifier is performed. For this purpose ~~To this end,~~ in a test engraving process test cells are engraved for prescribed desired tone values, for instance for the desired tone values "light", "dark" and "middle tone". After the test engraving, the geometric actual dimensions of the engraved test cells are measured out and compared to the corresponding desired dimensions. Settings are calculated from the comparison of the geometric dimensions, with which settings the engraving signal is calibrated such that the geometric dimensions of the cells that are actually created in the engraving correspond to the geometric dimensions required for an engraving with the correct tone values.

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SUMMARY OF THE INVENTION

In conventional calibration a1 of an engraving amplifier of an engraving machine, the settings are prescribed, the geometric dimensions of the test cells that are engraved in test engravings are measured out, and the new settings are calculated with the aid of the measurement results essentially manually, with the setting processes and subsequent test engravings being continued until an optimal calibration is reached. A disadvantage of the conventional procedure is that the operator must have practical experience concerning the relations between the electrical setting points and the actual geometric dimensions, which are to be expected, of the test cells, whereby numerous parameters and marginal conditions must be accounted for, such as the transmission behavior of the engraving amplifier and the engraving member, the cut angle and the degree of wear of the engraving stylus, as well as the material hardness of the surface of the printing cylinder that is to be engraved.

EP 0 595 324 A already reaches a method for calibrating an engraving amplifier of an engraving machine in which signal values for modifying at least one parameter “vibration”, “light”, “depth”, or “medium gradation” are set at the engraving amplifier, a test engraving is performed using the adjusted signal values, the actual dimensions of the engraved test cells are measured out, and, from the measured actual dimensions and the predetermined desired dimensions, difference values with which the signal values are corrected are calculated upon consideration of previously calculated transmission functions, with the individual steps being repeated in a routine using the respectively corrected signal values until the actual dimensions of the engraved test cells are within a tolerance range.

A similar method for calibrating an engraving amplifier of an engraving machine is known from US 5 438 422 A.

The known methods have the disadvantage that optimal calibration requires a relatively long time, since a new test engraving must always be conducted in the repetitions of the steps.

It is thus the object of the invention to improve a method for calibrating an engraving amplifier in an electronic engraving machine so as to shorten the time required for calibration.

This object is achieved by the features of claim 1.

Advantageous developments and further developments are given in the subclaims.

The invention is detailed below with the aid of the Figure, which represents a principal exemplifying embodiment for an electronic engraving machine for engraving printing cylinders for gravure printing. The engraving machine is a HelioKlischograph® by Hell Gravure Systems GmbH, Kiel, DE.

A printing cylinder (1) is driven to rotate by a cylinder drive (2). The engraving on the printing cylinder (1) is accomplished with the aid of an engraving member (3), which comprises an engraving stylus (4) as cutting tool.

The engraving member (3) is located on an engraving carriage (5), which is moved with the aid of a spindle (6) by an engraving carriage drive (7) in the axial direction of the printing cylinder (1).

The engraving stylus (4) of the engraving member (3) cuts a series of cells that are arranged in an engraving raster line by line into the surface of the rotating printing cylinder (1), while the engraving carriage (5) with the engraving member (3) moves axially along the printing cylinder in the forward direction.

The engraving stylus (4) of the engraving member (3) is controlled by an engraving signal G. The engraving signal G is formed in an engraving amplifier (8) by superimposing a periodic vibration signal R with image signal values B, which represent the tone values between "light" (white) and depth (black) of the cells that are to be engraved. While the periodic vibration signal R effectuates an oscillating lifting motion of the engraving stylus (4) for generating the engraving grid, the image signal values B in connection with the amplitude of the vibration signal R determine the geometric dimensions of the engraved cells such as cross-diagonals, longitudinal diagonals, ridge widths and penetration depth.

The image signal values B are obtained in a D/A converter (9) from engraving data GD, which are stored in an engraving data storage unit (10) and are read out of this line by line and fed to the D/A converter (9). Each engraving location for a cell is assigned an engraving datum in the engraving raster, which contains as engraving information the tone value between the tone values "light' and "depth" that is to be engraved.

The printing cylinder (1) is allocated an XY coordinate system, whose x axis is oriented in the axial direction and whose y axis is oriented in the circumferential direction of the printing cylinder (1). The x spatial coordinates of the engraving locations on the printing cylinder (1) that are arranged in the engraving raster are generated by the engraving carriage drive (7). A position transmitter (11) that is mechanically coupled to the cylinder drive (2) generates the corresponding y spatial coordinates of the engraving locations on the printing cylinder (1). The spatial coordinates (x,y) of the engraving locations are fed to a control unit (14) via lines (12,13).

The control unit (14) controls the addressing and readout of the engraving data GD from the engraving data storage unit (10) as a function of the xy coordinates of the current engraving locations via a line (15). The control unit (14) additionally generates the vibration signal R on a line (16) with the frequency required for generating the engraving raster.

For engraving test cells in a test engraving process that takes place prior to the actual engraving of the printing cylinder (1), the engraving machine comprises a test engraving computer (19), which delivers the required engraving data GD*, which represent the geometric desired dimensions of the test cells that are to be engraved, to the engraving amplifier (8) as digital/analog converted image signal values B.

To pick up a video image of the test cells that are generated in the test engraving process, a measurement carriage (20) that can be displaced in the axial direction of the printing cylinder (1) is provided with a video camera (21), which is connected via a line (22) to an image evaluating stage (23) for measuring out the geometric actual dimensions of the test cells in the video image. The measurement carriage (20) can be moved automatically to the required axial measuring positions via spindle (24) by a measurement carriage drive (25). The measurement carriage (25) is controlled by the control unit (14) by a control command on a line (26).

Alternatively, the video camera (21) can also be arranged in the region of the engraving member (3).

The geometric actual dimensions of the engraved test cells, which are detected in the image evaluation stage (23), are transferred via a line (27) to the test engraving computer (19) as measurement values M. In the test engraving computer (19), electrical settings E for the parameters "vibration", "light", "depth" and "medium gradation" are obtained by comparing the geometric actual dimensions to the predetermined geometric desired dimensions, and these settings are fed to the engraving amplifier (8) via a line (28). With the aid of the electrical setting values E, the vibration signal R and the engraving signal G are so calibrated in the engraving amplifier (8) that cells which are actually generated in the subsequent engraving of the printing cylinder (1) comprise the geometric desired dimensions that are required for an engraving process that is correct in terms of tone values. The calibration can be accomplished manually, but advantageously automatically by a dynamic control process, which can take place before or during the actual production of the printing form.

The inventive calibration with respect to the parameters "vibration", "light', "depth" and "medium gradation" consists of consecutive cycles or runs, where one run consist of the following steps [A] to [F]:

[A] input the electrical settings E_n for the individual parameters "vibration", "light", "depth" and "medium gradation" of a run (n),

[B] perform a test engraving with the inputted settings E_n,

[C] measure out the geometric actual dimensions of the engraved test cells,

[D] compare the geometric actual dimensions to the predetermined desired dimensions,

[E] ready transmission coefficients reproducing the relations between the variations of the electrical signal values and the resulting variations of the geometric dimensions of the engraved cells, and

[F] calculate difference values ΔE from the geometric actual dimensions and the desired dimensions of the engraved test cells and the transmission coefficients, and calculate new settings for the subsequent run (n+1) from the difference values ΔE according to the equation $E_{n+1} = E_n + \Delta E$.

The individual steps [A] to [F] of a run are detailed below.

Step A

In step [A] the electrical settings E_R, E_L, E_T and E_M for the individual parameters "vibration", "light", "depth" and "medium gradation" are inputted into the engraving amplifier (8), whereby the settings E_R control the amplitude of the vibration signal R, the settings E_L and E_T control the engraving signal values G_L and G_T for "light" and "depth", and the settings E_M control the engraving signal value G_M for correcting a medium gradation.

In run I, the settings E_I are generally experimental values; in the subsequent runs (n+1), they are the settings E_{n+1} that are computed in the step [E] of the preceding run (n).

Step [B]

In step [B] a test engraving process is carried out using the settings E_{Rn}, E_{Ln}, E_{Tn} and E_{Mn} that were inputted in step [A]. To generate the test cells, the test engraving computer (19) fetches the engraving data GD* for the desired values "depth", "light", and for at least one "medium gradation" between "light" and "depth", for example. The engraving data GD* represent the predetermined geometric desired dimensions of the test cells, for instance the desired cross-diagonals d'_{QL}, d'_{QT} and d'_{QM} as well as the width d'_k of the penetration or channel in test engravings with penetration. The fetched engraving data GD* are converted into the engraving signal G for the engraving member (3). The engraving member (3) engraves at least one test cell (30) for "light" (L), "depth" (T) and "medium gradation" (M) on adjacent engraving lines (29). Advantageously, several identical test cells (30) are engraved on every engraving line (29), for instance across a selectable engraving line region.

Step [C]

In step [C] the video camera (21) records a video image of the engraved test cells (30) in order to measure out the geometric actual dimensions, namely the cross-diagonals d''_{QL}, d''_{QT}, d''_{QM} and the width d''_{K} of the penetration of the engraved test cells (30) for "light", "depth" and "medium gradation", with the aid of the video image in the image evaluation stage (23) and to route these to the test engraving computer (19) as measurement values M. A method for automatic evaluation of a video image for the purpose of determining the geometric dimensions of test cells is described in depth in WO 98/55302 A (PCT/DE 98/01441).

In Step [D]

In step [D] the geometric actual dimensions d''_{QL}, d''_{QT}, d''_{QM} and d'_{K} and the corresponding geometric desired dimensions d'_{QL}, d'_{QT}, d'_{QM} and d'_{K} are compared to one another, and it is decided with the aid of the comparison result whether another run is necessary for optimizing the calibration, or the calibration can be concluded already. The calibration is concluded either when the measured actual dimensions match the desired dimensions or when the actual dimensions achieved are within a predetermined tolerance range about the predetermined desired dimensions. Instead of the cross-diagonals d''_{QL}, d''_{QT}, d''_{QM} of the cells, their longitudinal diagonals can also be observed.

Step [E]

In step [E] transmission coefficients "f" are made available, which account for the functional relations between the variations of electrical signal values ΔR, ΔG_L, ΔG_T and ΔG_M and the resulting variations of the geometric dimensions

Δd_{QL}, Δd_{QT}, Δd_{QM} and Δd_K of the engraved cells. These functional relations are described below.

A modification of the vibration signal ΔR for calibrating the parameter "vibration" influences the cross-diagonal d_{QT} and the penetration depth d_K of a cell representing the tone value "depth" according to the following relation (I):

$$\Delta(d_{QT}-d_K)=f(R)\times\Delta R \quad \text{(I)}$$

In addition, a modification of the vibration signal ΔR influences the cross-diagonals d_{QL}, d_{QT} and d_{QM} of the cells representing the tone values "light", "depth" and "medium gradation" according to the following relations (II), (III) and (IV):

$$\Delta d_{QL}(R) = f_L(R)\times\Delta R \qquad \text{(II)}$$

$$\Delta d_{QT}(R) = f_T(R)\times\Delta R \qquad \text{(III)}$$

$$\Delta d_{QM}(R) = f_M(R)\times\Delta R \qquad \text{(IV)}$$

A modification of the engraving signal value ΔG_L for calibrating the parameter "light" influences the cross-diagonal d_{QL} of a cell representing the tone value "light" according to the following relation (V):

$$\Delta d_{QL} = 1/f(G_L)\times\Delta G_L \qquad \text{(V)}$$

In addition, a modification of the engraving signal value ΔG_L influences the cross-diagonal d_{QM} of a cell representing the tone value "medium gradation" according to the following relation (VI):

$$\Delta d_{QM}(G_L)=f_M(G_L)\times\Delta G_L \qquad \text{(VI)}$$

Modification of the engraving signal value ΔG_T for calibrating the parameter "depth" influences the cross-diagonal d_{QT} of a cell representing the tone value "depth" according to the following relation (VII):

$$\Delta d_{QT}= 1/f(G_T)\times\Delta G_T \qquad \text{(VII)}$$

In addition, modification of the engraving signal value ΔG_T influences the cross-diagonal d_{QM} of a cell representing the tone value "medium gradation" according to the following relation (VIII):

$$\Delta d_{QM}(G_T) = f_M(G_T)\times\Delta G_T \qquad \text{(VIII)}$$

Correcting the medium gradation corrects the technical wear of the engraving stylus of an engraving member, which manifests itself namely by a reduced cell volume in cells representing a medium gradation. Modification of the engraving signal ΔG_M for medium gradation correction influences the cross-diagonal d_{QM} of a cell representing the medium gradation in accordance with the following relation (IV):

$$\Delta d_{QM} = 1/f(G_M) \times \Delta G_M \qquad (IX)$$

Under the assumption made in the described exemplifying embodiment that the relations are approximately linear, "f" is a coefficient of transmission, respectively. But in case the functional relations should not be linear, "f" can also be a respective transmission function. The given relations are directly dependent on the type of signal processing. Based on a different signal processing process, the scope of the functional relations can change.

The various coefficients of transmission f in the relations (I) to (IX), which reproduce the overall transmission function of the engraving machine between the electrical settings at the input side and the geometric dimensions of the engraved cells at the output side, are advantageously computed prior to calibration with the aid of test engravings and stored for later use in the test engraving computer (19).

<u>Step [F]</u>

In step [E] **[sic]**, for the subsequent run $(n+1)$ a new vibration signal value R_{n+1} and new engraving signal values G_{Ln+1}, G_{Tn+1} and G_{Mn+1} for the individual parameters "vibration", "light", "depth" and "medium gradation" are calculated.

<u>Parameter "Vibration"</u>

First, upon consideration of relation (I), a difference value ΔR for the vibration signal R is calculated from the measured actual dimensions d''_{QT} and d''_K, the desired dimensions d'_{QT} and d'_K and the transmission coefficient f(R) just calculated, in accordance with equation (X).

$$\Delta R = 1/f(R)[d'_{QT} - d'_K) - (d''_{QT}-d''_K)] \qquad (X)$$

Next, the vibration signal value R_{n+1} for the new run (n+1) is calculated from the difference value ΔR that was calculated according to equation (X) and the vibration signal R_n of the preceding run (n), in accordance with equation (XI).

$$R_{n+1} = R_n + \Delta R \qquad (XI)$$

This vibration signal value R_{n+1} is entered into the engraving amplifier (8) for a new run (n+1) by corresponding setting value E_R.

Parameter "light"

First, a fictive cross-diagonal d^*_{QL} is calculated as the sum of the measured cross-diagonals d''_{QL} and a cross-diagonal variation $\Delta d_{QL}(R)$, which has arisen based on the variation ΔR of the vibration signal according to relation (II), in accordance with equation (XII).

$$d^*_{QL} = d''_{QL} + \Delta d_{QL}(R) \qquad (XII)$$

With the aid of the fictive cross-diagonals d^*_{QL}, it is ascertained how to modify the engraving signal value ΔG_L in order to achieve the desired cross-diagonal d'_{QL}.

To do this, first the deviation Δd_{QL} of the fictive cross-diagonals d^*_{QL} from the desired cross-diagonals d'_{QL} is calculated according to equation (XIII).

$$\Delta d_{QL} = d^*_{QL}-d'_{QL} \qquad (XIII)$$

From the relation (V), the modification of the engraving signal value ΔG_L that is required for the correction of the deviation Δd_{QL} is then calculated upon consideration of the previously calculated transmission coefficient $f(G_L)$, in accordance with equation (XIV).

$$\Delta G_L = f(G_L) \times \Delta d_{QL} \qquad (XIV)$$

Thus the new engraving signal value G_{Ln+1} for the run (n+1) derives in accordance with equation (XV).

$$G_{Ln+1} = G_{Ln} + \Delta G_L \quad \text{(XV)}$$

This engraving signal value G_{Ln+1} is entered into the engraving amplifier (8) for a new run by a corresponding setting value E_L.

Parameter "depth"

First, a fictive cross-diagonal d^*_{QT} is calculated as the sum of the measured cross-diagonals d''_{QT} and a cross-diagonal variation $\Delta d_{QT}(R)$, which has arisen based on the variation ΔR of the vibration signal according to relation (III), in accordance with equation (XVI).

$$d^*_{QT} = d''_{QT} + \Delta d_{QT}(R) \qquad \text{(XVI)}$$

With the aid of the fictive cross-diagonals d^*_{QT}, it is ascertained how to modify the engraving signal value ΔG_T in order to achieve the desired cross-diagonal d'_{QT}.

To do this, first the deviation Δd_{QT} of the fictive cross-diagonals d^*_{QT} from the desired cross-diagonal d'_{QT} is calculated according to equation (XVII).

$$\Delta d_{QT} = d^*_{QT} - d'_{QT} \qquad \text{(XVII)}$$

From the relation (VII), the modification of the engraving signal value ΔG_T that is required for the correction of the deviation Δd_{QT} is then calculated upon consideration of the previously calculated transmission coefficient $f(G_T)$, in accordance with equation (XVIII).

$$\Delta G_T = f(G_T) \times \Delta d_{QT} \qquad \text{(XVIII)}$$

Thus the new engraving signal value G_{Ln+1} for the run (n+1) derives in accordance with equation (IXX).

$$G_{Tn+1} = G_{Tn} + \Delta G_T \quad \text{(IXX)}$$

This engraving signal value G_{Tn+1} is entered into the engraving amplifier (8) for a new run by a corresponding setting value E_T.

Parameter "medium gradation"

First, a fictive cross-diagonal d^*_{QM} is calculated as the sum of the measured cross-diagonals d''_{QM} and the cross-diagonal variations $\Delta d_{QM}(R)$, $\Delta d_{QM}(G_L)$ and $\Delta d_{QM}(G_T)$, in accordance with equation (XX). The cross-diagonal variations $\Delta d_{QM}(R)$, $\Delta d_{QM}(G_L)$ and $\Delta d_{QM}(G_T)$ arise based on the modification ΔR of the vibration signal R in accordance with the relation (IV) and the variations ΔG_L and ΔG_T of the engraving signal values G, in accordance with the relations (VI) and (VIII).

$$d^*_{QM} = d''_{QM} + \Delta d_{QM}(R) + \Delta d_{QM}(G_L) + \Delta_{QM}(G_T) \qquad (XX)$$

With the aid of the fictive cross-diagonals d^*_{QM}, it is ascertained how to modify the engraving signal value ΔG_M in order to achieve the desired cross-diagonal d'_{QM}.

To do this, first the deviation Δd_{QM} of the fictive cross-diagonals d^*_{QM} from the desired cross-diagonals d'_{QM} is calculated according to equation (XXI).

$$\Delta d_{QM} = d^*_{QM} - d'_{QM} \qquad (XXI)$$

From the relation (IV), the modification of the engraving signal ΔG_M that is required for the correction of the deviation Δd_{QM} is then calculated upon consideration of the previously calculated transmission coefficient $f(G_M)$, in accordance with equation (XXII).

$$\Delta G_M = f(G_M) \times \Delta d_{QM} \qquad (XXII)$$

Thus the new engraving signal value G_{Mn+1} for the run (n+1) derives in accordance with equation (XXIII):

$$G_{Mn+1} = G_{Mn} + \Delta G_M \qquad (XXIII)$$

This engraving signal value G_{Mn+1} is entered into the engraving amplifier (8) for a new run by a corresponding setting value E_M.

The individual runs are repeated while maintaining the transmission coefficients f until it is ascertained either that the measured actual dimensions match the desired dimensions or that the actual dimensions achieved are within a predetermined tolerance range about the predetermined desired dimensions.

In order to reduce the number of individual runs and thus achieve a more rapid calibration, it is suggested as an advantageous development to determine the differences between the desired dimensions d'_{QT}, d'_{QL}, d'_{QM} and d'_K and the respectively achieved actual dimensions d''_{QT}, d''_{QL}, d''_{QM} and d''_K in step [D], at least within one run (n), preferably within the second run II, and, if the differences is **[sic]** greater than a predetermined tolerance range below the desired dimensions, to compute improved transmission coefficients f' in step [E] in the sense of a more rapid approximating of the desired dimensions by the actual dimensions, and then in step [F] to calculate a corrected vibration signal value R_{n+1} and corrected engraving signal values G_{Ln+1}, G_{Tn+1} and G_{Mn+1} for the subsequent run (n+1) with the aid of the new transmission coefficients f', in order to achieve a fast calibration. The improved transmission coefficients f'can be stored and used advantageously for a later calibration prior to the engraving of a new printing cylinder (1).

The determining of the improved transmission coefficients f', which reproduce relations between the adjusted electrical settings E_n (R_n, G_{Ln}, G_{Tn}, G_{Mn}) and the measured geometric dimensions $d''_n(d''_{QL}, d''_{QT}, d''_{QM}, d''_K)$, is accomplished by difference formation between the settings E_n and E_{n+1} and by difference formation between the measured geometric dimensions d_n and d_{n+1} of two consecutive runs (n) and (n+1) by the following general schema:

$$\begin{array}{lll} \text{run n:} & \text{setting } E_n & \Rightarrow f \Rightarrow \text{measured dimensions } d''_n \\ \text{run (n+1):} & \text{setting } E_{n+1} & \Rightarrow f \Rightarrow \text{ measured deviations } d''_{n+1} \\ \hline \text{Difference formation:} & \Delta(E_n - E_{n+1}) & \Rightarrow f' \Rightarrow \ \Delta(d''_n - d''_{n+1}) \end{array}$$

The calculation of an improved transmission coefficient f' is described further in the example of the parameter "vibration".

A first vibration signal value R_I which is entered in the first run I yields the geometric dimensions d_{QTI} and d_{KI} in the first measurement. A second vibration signal value R_{II} which is entered in the second run II yields the geometric dimensions d_{QTII} and d_{KII} in the second measurement. Upon difference formation, the improved transmission coefficient f′ for the parameter "vibration" can be calculated in accordance with equation (XIV), given known ΔR and known geometric dimensions:

$$\Delta R = (R_{II} - R_{I}) = f'[(d''_{QTII} - d''_{QTI}) - (d''_{KII} - d''_{KI})] \qquad \text{(XIV)}$$

Improved transmission coefficients f′ are determined analogously for the other parameters "light", "depth", and "medium gradation".